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OFGS File No. : IR-1785 (2-2408)
Inventor : Ajit Dubhashi; Shahin Maloyan and Joshua Polack
Title : POWER ASSEMBLY WITH INTEGRATED CURRENT SENSING
Assignee : International Rectifier Corporation

Enclosed herewith please find the following documents in the above-identified application for United States Letters Patent:

10 Pages of Specification including Abstract and Claims
19 Numbered Claims Calculated as 19 Claims for Fee Purposes
2 Sheet of Drawing Containing Figures 1 to 4. (formal)
X Declaration and Power of Attorney
_____ Priority is Claimed under 35 U.S.C. §119:
Convention Date _____ for _____ Appln. S.N. _____
____ Certified Priority Application
____ Verified Statement Claiming Small Entity Status under 37 C.F.R. §1.27.
X Assignment
X Return-Addressed Post Card

OFGS Check No. 1184, which includes the fee of $730.00, calculated as follows:

Basic Filing Fee:	$ 690.00
Additional Filing Fees:	
Total Number of Claims in Excess of 20, times $18:	-0-
Number of Independent Claims in Excess of 3, times $78: . .	-0-
One or More Multiple Dependent Claims: Total $260.	-0-
Total Filing Fees or	$ 690.00
Total Filing Fee Reduced 50% for Small Entity:	-0-
Assignment Recording Fee: $40	40.00
TOTAL Filing Fee and Assignment Recording Fee:	$ 730.00

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EXPRESS MAIL CERTIFICATE

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Dorothy Jenkins
Name of Person Mailing Correspondence

Dorothy Jenkins
Signature

September 13, 2000
Date of Signature

Respectfully submitted,

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TITLE: POWER ASSEMBLY WITH INTEGRATED CURRENT SENSING

FIELD OF THE INVENTION

This invention relates to a current sensing structure and more specifically relates to a novel current sensing structure for power semiconductor device module assemblies. This application claims the benefit of provisional application Serial No. 60/154,283 filed September 16, 1999.

BACKGROUND OF THE INVENTION

Most power electronic applications require knowledge of the current in the system, either in the load or in the switches. This is usually used to protect the system, the power conversion devices or to enhance system performance. Current monitoring is done in many ways such as by current transformers ("CTs"), shunt resistors, current sensing devices and DC current probes based on Hall effect devices which are coupled with gapped core and coil assemblies. Current transformers cannot be used in applications that require sensing of low frequency currents. Shunt resistors are limited in their application range to a maximum of a few tens of amperes. DC current probes based on the Hall effect are expensive and add cost to the system assembly.

BRIEF DESCRIPTION OF THE INVENTION

In accordance with the invention, the driver printed circuit board ("PCB") of a power module carries a current sensor such as commercially available Hall effect device (without magnetics) disposed at an edge of the board and

positioned in the magnetic field that is created by the conductors carrying the current to and from the module. Magnetic bars or bodies may also be fastened to the board to focus or increase flux in the current sensor.

Some of the features of the present invention are:

1. Including a Hall effect or other current sensing assembly such as magnetostrictive devices in the module and placing it in a position to detect the field.

2. Ensuring a way to place the current sensor device in an accurate orientation with respect to the current carrying conductor.

3. Using the output of the device to trip a comparator to protect the switches or system.

4. Making the output of the device available to a controller for improving system performance.

5. In cases where the current is not strong enough to create the requisite magnetic field, adding appropriate bars of ferrite, iron or similar ferro magnetic material which allows an increase in the flux density through the sensor for a given current.

6. Bending the current carrying conductor whose current is to be measured in a particular direction to increase or decrease the amount of flux in the sensing device.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a view of the base of the assembly of the invention and is a cross-section of Figure 3 taken across section lines 1-1 in Figure 3.

Figure 2 is a view of the top of the printed circuit board of the invention and is a view of Figure 3 taken across section lines 2-2 in Figure 3.

Figure 3 is a cross-section of Figure 2 taken across section line 3-3 in Figure 2.

Figure 4 is a cross-section of Figure 3 taken across section line 4-4 in Figure 3.

DETAILED DESCRIPTION OF THE DRAWINGS

Referring first to Figure 1, there is shown a heat sink base plate 10 which may be of any desired metal 11 having an insulation top layer 12 (Figure 3 and 4) and conductive copper pad areas 13 and 14. Any desired pattern of pads, depending on the desired circuit arrangement of power devices thereon can be used. Thus in Figures 1 and 2, a single power semiconductor device 20, shown as a power MOSFET. However, the power device could be any other MOSgated device such as an IGBT, or any other power semiconductor device such as a bipolar transistor, thyristor or the like. Further, any desired number of devices can be used.

Device 20 has its bottom power electrode (drain) secured to conductive pad 20 as by solder, or conductive epoxy or the like. The drain may be suitably connected with a current carrying terminal conductor 30, which is a rigid, L-shaped thin, flat and copper bar which has its lower leg 31 soldered or connected by a conductive epoxy to pad 14 and is suitably arranged so that it carries the source to drain current of device 20. A plurality of parallel wire bonds 33, 34 connect the source electrode 35 (Figure 1) of MOSFET 20 to the upright leg 31 of current conductor 30.

In order to control the conduction of MOSFET 20 as desired, a control circuit is carried on a conventional thin flat printed circuit board 40 which is mounted above and parallel to base 10. Suitable insulation support posts 41, 42 and 43 may extend between base 10 and board 40 for this support function. Board 40

may carry any desired control circuit 45 and a control integrated circuit chip 46 (Figures 2 and 3) to control MOSFET 20. Thus, the MOSFET gate electrode 50 (Figure 1)is coupled to the control circuit as shown by the dotted line 51 in Figures 1 and 3.

To this point, the structure described is generic to many known types of power semiconductor device modules. In accordance with the invention, a magnetic field responsive transducer 60 is mounted as by adhesive or the like or solder on the board 40 adjacent an end edge of the board. Thus, in Figures 2 and 3, the board has a thin elongated slit 70 thereon which defines an interior end edge 71. (The edge could also have been on the outermost board edge 72 if desired). The rigid current conductor 30 then extends adjacent to edge 71 in its upward extending path to the exterior of the module. Preferably, the vertical portion of conductor 30 is perpendicular to the plane of board 40, but it can be at any angle thereto greater than zero.

By placing the sensor 60, which is preferably a Hall effect element or a magneto resistive device (MRD), adjacent the edge 71, the Hall element will be in the path of and will intercept the magnetic field lines produced by the current in conductor 30, as shown in Figure 2. Details of the structure of the Hall effect element and MRD, including input and output terminals and biases are well known and are not described herein. The Hall element 60, or other sensor, will then produce an output voltage proportional to the field and thus to the current in conductor 30. This output signal can then be coupled back to the IC 46, as shown by dotted lines 80 in Figures 2 and 3 to effect a desired control of MOSFET 20 in response to its source to drain current. In addition to the described physical relative locations of the sensing device and the current carrying conductor. There could be other locations.

Bars 90 and 91 of a magnetic material such as ferrite, or ferromagnetic material may be added to increase the flux in the sensing device area. These bars may be used to permit accurate measurement of lower currents, for example 25 to 100 amperes. When currents in excess of 400 amperes are to be measured, the bars 90 and 91 may not necessary based on the sensitivity of the sense.

Although the present invention has been described in relation to particular embodiments thereof, many other variations and modifications and other uses will become apparent to those skilled in the art. It is preferred, therefore, that the present invention be limited not by the specific disclosure herein.

WHAT IS CLAIMED IS:

1. A current sensing structure for a power semiconductor device, said semiconductor device having at least one power electrode and a control electrode; said power electrode connected to an elongated conductive terminal electrode, said current sensing structure including a printed circuit board having a control circuit thereon which is connected to said control electrode to control current flow in said power semiconductor device; said printed circuit board being spaced from said semiconductor device; said printed circuit board having an edge portion; said printed circuit board having an edge portion; said printed circuit board having a magnetic field responsive transducer thereon disposed adjacent said edge portion, said transducer producing an output signal which is related to a magnetic field which is intercepted by said transducer; said elongated terminal conductor having a portion thereof which is disposed adjacent said edge portion and is at an angle greater than zero degrees with respect thereto, whereby the magnetic field produced by current through said elongated terminal conductor is intercepted by said magnetic field responsive transducer and produces an output therefrom which is related to the current in said elongated terminal conductor.

2. The structure of claim 1, wherein said transducer is a Hall sensor.

3. The structure of claim 2, wherein said elongated terminal conductor terminal is a rigid conductor.

4. The structure of claim 3, wherein said elongated terminal conductor is a flat relatively thin conductor.

5. The structure of claim 1, which further includes a flat elongated heat sink; said semiconductor device having a bottom electrode secured to said base; said printed circuit board being mounted atop said base and spaced therefrom and extending parallel thereto.

6. The structure of claim 5, wherein said elongated terminal conductor is a flat relatively thin conductor.

7. The structure of claim 6, wherein said elongated terminal conductor is an L-shaped bracket having its bottom surface mounted on said base.

8. The structure of claim 1, wherein said printed circuit board has an elongated slot therein; said edge comprising an interior edge of said slot; said elongated terminal conductor extending through said slot.

9. The structure of claim 3, wherein said elongated terminal conductor extends perpendicular to the plane of said printed circuit board.

10. The structure of claim 7, wherein said elongated terminal conductor is a rigid conductor.

11. The structure of claim 1, which further includes at least one magnetic body disposed adjacent said transducer and in line with the magnetic field path of said elongated terminal conductor to increase the magnetic flux intercepted by said transducer.

12. The structure of claim 11, wherein said transducer is a Hall sensor.

13. The structure of claim 12, wherein said elongated terminal conductor is a flat relatively thin conductor.

14. The structure of claim 13, which further includes a flat elongated heat sink; said semiconductor device having a bottom electrode secured to said base; said printed circuit board being mounted atop said base and spaced therefrom and extending parallel thereto.

15. The structure of claim 14, wherein said printed circuit board has an elongated slot therein; said edge comprising an interior edge of said slot; said elongated terminal conductor extending through said slot.

16. A current sense structure for sensing the current in an elongated conductor; said current sense structure comprising a printed circuit board having an edge portion; a magnetic field transducer mounted on the surface of said printed circuit board and adjacent said edge portion; said elongated current conductor being disposed adjacent said edge portion and said current sensor and extending generally perpendicular to said printed circuit device; whereby the magnetic field created by current in said conductor circulated said transducer to induce an output therefrom related to the current in said conductor.

17. The structure of claim 16, wherein said transducer is a Hall sensor.

18. The structure of claim 16, wherein said printed circuit board has an elongated slot therein; said edge portion comprising an edge of said slot; said elongated conductor extending through said slot.

19. The structure of claim 16, which further includes at least one magnetic body disposed adjacent said transducer and in line with the magnetic field of said elongated conductor to increase the magnetic flux intercepted by said transducer.

IR-1785 (2-2174)

POWER ASSEMBLY WITH
INTEGRATED CURRENT SENSING

ABSTRACT OF THE DISCLOSURE

A semiconductor module has a conductive heat sink base which receives a power semiconductor and a printed circuit board mounted above the heat sink and carrying control circuits for the power semiconductor. A rigid L-shaped terminal connected to one electrode of the power semiconductor is mounted on the base and extends upward and adjacent an edge of the printed circuit board. A Hall sensor is mounted on the printed circuit board and is disposed in and intercepts the magnetic field produced by current in the terminal. Magnetic bodies are mounted on opposite sides of the Hall element to concentrate the magnetic field through the Hall sensor.

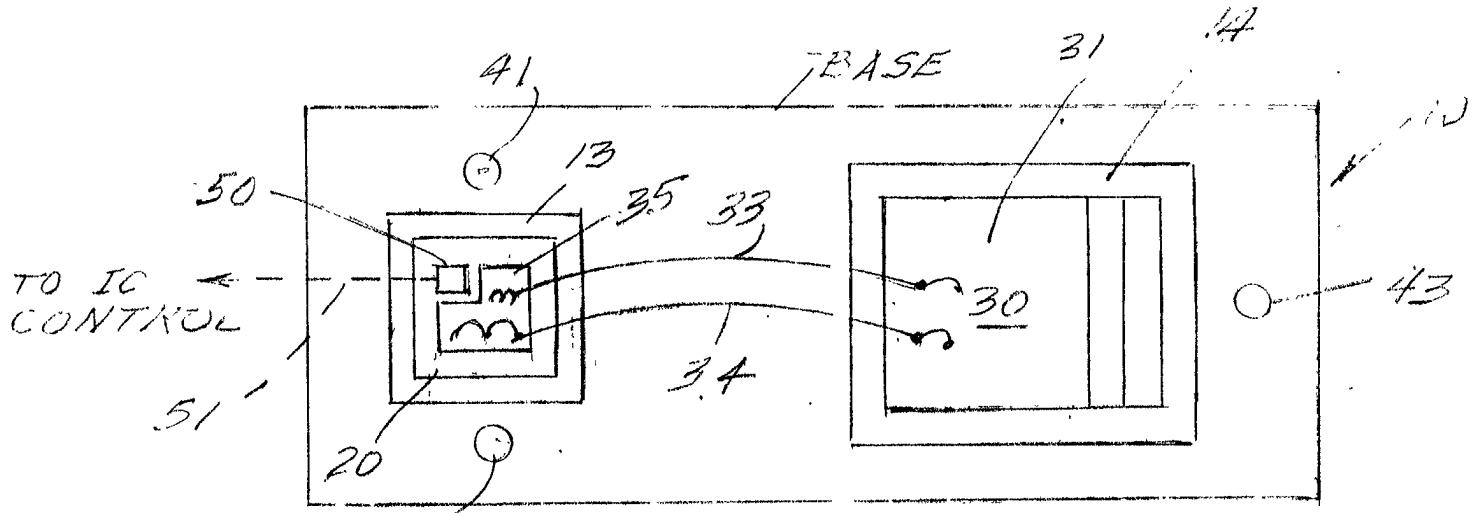

FIG. 1

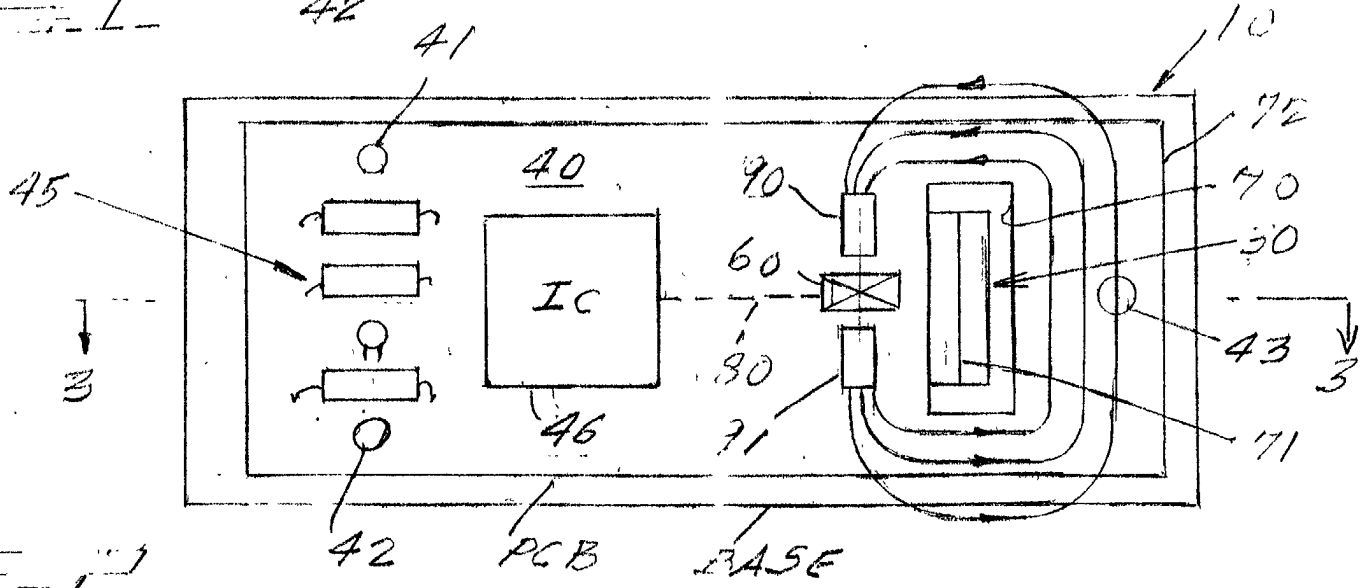

FIG. 2

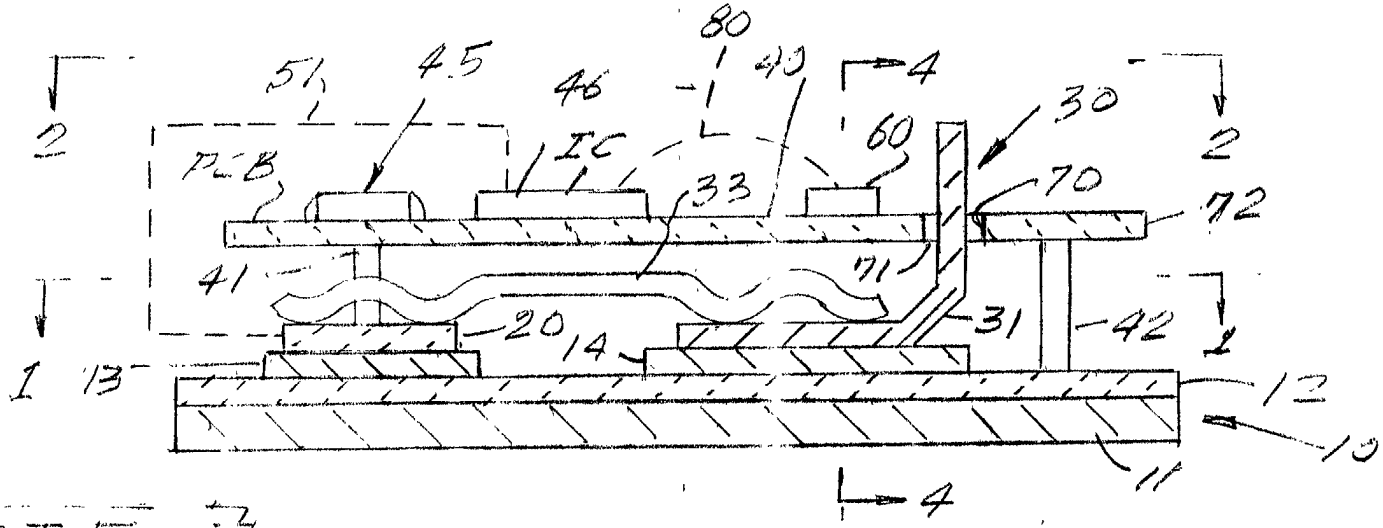

FIG. 3

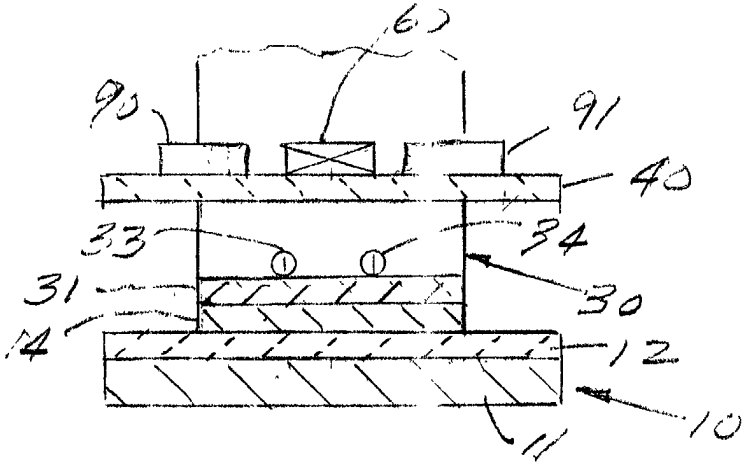

FIG. 4

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As a below named inventor, I hereby declare that: my residence, post office address and citizenship are as stated below next to my name; that I verily believe that I am the original, first and sole inventor (if only one name is listed below) or a joint inventor (if plural inventors are named) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

POWER ASSEMBLY WITH INTEGRATED CURRENT SENSING

the specification of which is attached hereto, unless the following box is checked:

☐ was filed on _____ as United States patent Application Number or PCT International patent application number _____ and was amended on _____ (if any).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose all information known to be material to patentability in accordance with Title 37, Code of Federal Regulations, §1.56.

I hereby claim priority benefits under Title 35, United States Code §119 of any foreign application(s) for patent or inventor's certificate or United States provisional application(s) listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign or Provisional Application(s)

COUNTRY	APPLICATION NUMBER	DATE OF FILING *(day, month, year)*	PRIORITY CLAIMED UNDER 35 U.S.C. 119
U.S.A.	60/154,283	16 SEPTEMBER 1999	YES X NO ___
			YES ___ NO ___
			YES ___ NO ___

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, §1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

UNITED STATES APPLICATION NUMBER	DATE OF FILING *(day, month, year)*	STATUS *(patented, pending, abandoned)*

I hereby appoint customer no. 2352 OSTROLENK, FABER, GERB & SOFFEN, LLP, and the members of the firm, Samuel H. Weiner - Reg. No. 18,510; Jerome M. Berliner - Reg. No. 18,653; Robert C. Faber - Reg. No. 24,322; Edward A. Meilman - Reg. No. 24,735; Stanley H. Lieberstein - Reg. No. 22,400; Steven I. Weisburd - Reg. No. 27,409; Max Moskowitz - Reg. No. 30,576; Stephen A. Soffen - Reg. No. 31,063; James A. Finder - Reg. No. 30,173; William O. Gray, III - Reg. No. 30,944; Louis C. Dujmich - Reg. No. 30,625 and Douglas A. Miro - Reg. No. 31,643, as attorneys with full power of substitution and revocation to prosecute this application, to transact all business in the Patent & Trademark Office connected therewith and to receive all correspondence.

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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UNITED STATES OF AMERICA COMBINED DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION	OFGS FILE NO. IR-1785 (2-2408)

As a below named inventor, I hereby declare that: my residence, post office address and citizenship are as stated below next to my name; that I verily believe that I am the original, first and sole inventor (if only one name is listed below) or a joint inventor (if plural inventors are named) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

POWER ASSEMBLY WITH INTEGRATED CURRENT SENSING

the specification of which is attached hereto, unless the following box is checked:

☐ was filed on _____ as United States patent Application Number or PCT International patent application number _____ and was amended on _____ (if any).

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			YES ___ NO ___

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